Innovative Testing of Ontario’s Asphalt Materials

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Ames, Iowa
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Presentation Outline

- Background
- Moisture Sensitivity Tests
- Hamburg Wheel Tracking Test
- Performance Tests using AMPT
- Future Work
  - Performance Tests using DTS-30
  - Bitumen Bond Strength Test (BBS)
- Binder Test Highlights
- Conclusions
Background

- MTO was 100% Superpave mix design by 2005
  - Superpave has mitigated rutting
  - Cracking is still a concern
- Establishing mix performance testing for design and acceptance of placed mix remains a goal
- Work in this area is expected to be ramping up
Stripping by Static Immersion Test

- Determines the stripping susceptibility of the different components of an asphalt mix (MTO LS-285)
- Aggregates are blended with asphalt cement and the blended material is submerged in distilled water at 49°C for 24 hours
- Stripping susceptibility of the asphalt mix is assessed visually based on the percentage of the retained coating on the aggregate

~15% retained coating

~85% retained coating
The percent coating of various samples can be compared to determine what aggregate, AC, and anti-stripping treatment combination, provides better moisture resistance.

Minimum satisfactory value for this test is 65% retained coating.

<table>
<thead>
<tr>
<th>Aggregate Type</th>
<th>No Treatment</th>
<th>Hydrated Lime</th>
<th>Alternative AST-AGG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granite</td>
<td>15%</td>
<td>85%</td>
<td>90%</td>
</tr>
</tbody>
</table>
Tensile Strength Ratio (TSR)

- Determines the change in tensile strength resulting from moisture conditioning followed by a freeze-thaw cycle of compacted asphalt mixtures (AASHTO T283)
- Test is used during mix design to determine susceptibility of an asphalt mix to moisture damage
- In some cases we find this to be insufficient and specify anti-strip to minimize risk of stripping
Moisture Induced Stress Tester (MIST)

- An alternative moisture conditioning process to the TSR’s freeze/thaw conditioning
- In addition to a conditioning process, MIST can be used to evaluate specimens based on sample swelling
- Air voids are measured and the percent swelling is calculated using

\[
Swelling = \frac{(BRD_{before} - BRD_{after})}{BRD_{before}}
\]

Where:

- \(BRD_{before}\) = Bulk Relative Density prior to MIST conditioning
- \(BRD_{after}\) = Bulk Relative Density after MIST conditioning
Moisture Sensitivity Test Results

- The results of liquid anti-stripping treatments (AST-AC) for the moisture sensitivity are:

<table>
<thead>
<tr>
<th>Aggregate Type</th>
<th>Static Immersion</th>
<th>TSR</th>
<th>MIST -TSR</th>
<th>MIST-Swelling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No AST</td>
<td>AST-AC</td>
<td>No AST</td>
<td>AST-AC</td>
</tr>
<tr>
<td>Granite</td>
<td>15%</td>
<td>90%</td>
<td>67%</td>
<td>98%</td>
</tr>
<tr>
<td>Diabase</td>
<td>98%</td>
<td>*</td>
<td>84%</td>
<td>98%</td>
</tr>
</tbody>
</table>

* Not tested

- The sample with the lowest retained coating, also has the lowest TSR, MIST-TSR and highest swelling value

- Alternately, the diabase had greatest retained coating without AST, the highest TSR, MIST-TSR and lowest swelling

- Testing has resumed using Dolomitic Sandstone aggregate
Hamburg Wheel Tracking Test (HWT)

- MTO uses our Hamburg Wheel Tracking Machine to:
  - Evaluate mixes made with various antistripping additives
  - Evaluate specialty mixes (e.g., fiber reinforced HMA)
  - Investigate premature pavement failure

- Have not used the HWT test to evaluate mixes before they are used in production or to evaluate mix during production
AMPT

MTO owns an AMPT (IPC Global) that can run the following tests:

- Dynamic Modulus
- Flow Number
- S-VECD
- Texas Overlay
Performance Testing using DTS-30

- MTO is purchasing a Dynamic Testing System (DTS-30) that will allow us to run the following:
  - Dynamic Modulus
  - Flow Number
  - Simplified Visco Elastic Continuum Damage (S-VECD)
  - Texas Overlay
  - Four Point Bending
  - Semicircular Bend (SCB)
  - Disk-Shaped Compact Tension (DCT)
  - Indirect Tensile (IDT) Creep Compliance and Strength
  - Resilient Modulus
  - TSRST (Thermal Stress Restrained Specimen Test)
Bitumen Bond Strength Test (BBS)

- The BBS test is a simple procedure to measure moisture resistance of the asphalt-aggregate interface for different combinations of materials.

- “Pull-Off Strength of Coatings Using Portable Adhesion Testers”. (ASTM D4541)

- Just acquired the device.
Future Work

- More testing is planned with MIST and Bitumen Bond Strength Test (BBS)
- MTO is embarking on a large mix testing program (mainly involving SCB, DCT, IDT, HWT)
- Also looking at enhancing our recovery process when evaluating production mix:
  - Currently run RTFO after recovery
  - Solvents used
- MTO will explore testing production mix
- Considering proposals to establish a digital image process that measures the risk of Stripping by Static Immersion
Asphalt Cement Test Innovations

- Ash Content Test
- Extended Bending Beam Rheometer (ExBBR) Test
- X-Ray Fluorescence (XRF)
- Fourier Transform Infrared (FTIR) Spectroscopy
Ash Content Test

- Ash Content test was implemented to prevent over-modification with Re-Refined Engine Oil Bottoms (REOB)

  - Analysis of over 80 samples showed an excellent correlation between ash content and estimated REOB content
  - Limited analysis to date shows excellent correlation between 5 year pavement cracking and ash content

\[
R^2 = 0.74
\]

\[
R^2 = 0.81
\]
Extended Bending Beam Rheometer (ExBBR) Test

- Determines if AC meets the low temperature performance grade after a physical hardening process that occurs with extended conditioning at cool temperatures.

- Test is published as AASHTO TP122-16.

- Found best able to predict cracking.

- ExBBR determines low temperature grade over 72 hours vs. 1 hour for standard grading.
Estimation of 72 Hour Stiffness and Creep

- MTO developed multivariable regression formulae to predict the 72 hour ExBBR test based on 1 and 24 hour properties:

\[
\begin{align*}
\text{m-value at 72 hrs (T}_{ht}) &= 0.03239*(\text{m-value @ 1 hr}) + 0.88952*(\text{m-value @ 24 hr}) + 0.01129 \\
\text{m-value at 72 hrs (T}_{lt}) &= 0.17770*(\text{m-value @ 1 hr}) + 0.795125*(\text{m-value @ 24 hr}) -0.00869 \\
\text{S at 72 hrs (T}_{ht}) &= 0.13495*(\text{S @ 1 hr}) + 0.94721*(\text{S @ 24 hr}) + 3.34123 \\
\text{S at 72 hrs (T}_{lt}) &= 0.16874*(\text{S @ 1 hr}) + 0.93364*(\text{S @ 24 hr}) + 0.14202
\end{align*}
\]

Where:

- \(T_{ht}\) = high test temperature
- \(T_{lt}\) = low test temperature

- Regression analysis was conducted on over 330 ExBBR tests

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Estimation of 72 Hour Stiffness and Creep

- The predicted m-value and S can be used to estimate ExBBR Low Temperature Limiting Grade that could be useful for quality control purposes.

R² = 0.94

Actual m-value at 72Hr

R² = 0.99

Actual S at 72Hr
Δ𝑇_𝑐 From BBR/ExBBR Test

- Another useful outcome from the BBR test is the Δ𝑇_𝑐:

\[ \Delta T_c = T_{stiffness} - T_{creep} \]

Where:
- \( T_{stiffness} \) = critical temperature for stiffness (S)
- \( T_{creep} \) = critical temperature for creep (m-value)

- Of the 62 samples tested, no BBR Δ𝑇_𝑐’s where <-5, only ExBBR Δ𝑇_𝑐’s dropped below -5, while REOB estimates for these samples ranged from 0 to just over 12%

- Recent results:
  - For a PG64-28 was -7.9
  - For recovered AC with and without RAP and RAS, Δ𝑇_𝑐 ranged from -4.2 to -8.3
Estimated REOB Content vs. $\Delta T_c$

- $R^2 = 0.29$
- $R^2 = 0.31$

$\Delta T_c < -5$
X-Ray Fluorescence (XRF)

- XRF detects the elemental content of a sample
- Transportation agencies, including MTO, are looking at XRF to identify over-modification of REOB in asphalt cement
- Elemental intensity peaks obtained are all relative to other elements found, so calibration curves are required for each element in a material to be quantified (in ppm)
- The four key elements and the levels detected in a REOB sample are:
  - Calcium: 10,000 ppm
  - Zinc: 3,000 ppm
  - Molybdenum: 300 ppm
  - Copper: 100 ppm
X-Ray Fluorescence (XRF)

- MTO created calibration curves from base asphalt cement samples with varying percentages of REOB
- A linear regression curve was created for each element
- Equations currently used by MTO for estimating REOB content based on each element follow:

<table>
<thead>
<tr>
<th>Element</th>
<th>Equation for Estimating REOB Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>[ REOB% (Ca) = \frac{XRF(Ca) - 16}{109} ]</td>
</tr>
<tr>
<td>Zinc</td>
<td>[ REOB% (Zn) = \frac{XRF(Zn) - 14}{48} ]</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>[ REOB% (Mo) = \frac{XRF(Mo) - 18}{4} ]</td>
</tr>
<tr>
<td>Copper</td>
<td>[ REOB% (Cu) = \frac{XRF(Cu)}{1.5} ]</td>
</tr>
</tbody>
</table>
Fourier Transform Infrared (FTIR) Spectroscopy

- FTIR detects the infrared energy absorbed in a sample
- Comparing FTIR spectra of an unknown sample to a “standard” sample can be used to spot modifications made to an “unknown” sample
- FTIR also provides information on the molecular bond and functional groups of modifications that are made to a material
- We found a unique FTIR absorbance peak corresponding to REOB
- The peak was observed near wavenumber 1229 cm\(^{-1}\) - believed to correspond to polyisobutylene, an additive used in engine oil
FTIR Spectra

Unmodified AC
REOB 1
REOB 2
Used Motor Oil
REOB Estimation using FTIR and XRF

- FTIR can identify whether REOB is present in the AC
- MTO is estimating % REOB in AC with XRF
- Results are provided below for:
  - comparison between FTIR peak and XRF estimated REOB content; and
  - five year pavement cracking performance

<table>
<thead>
<tr>
<th>Sample</th>
<th>FTIR Absorption at 1229 cm⁻¹</th>
<th>XRF Count (ppm)</th>
<th>Average REOB Estimate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peak Present?</td>
<td>Ca</td>
<td>Cu</td>
</tr>
<tr>
<td>1</td>
<td>172</td>
<td>Yes</td>
<td>937</td>
</tr>
<tr>
<td>2</td>
<td>181</td>
<td>Yes</td>
<td>1378</td>
</tr>
<tr>
<td>3</td>
<td>135</td>
<td>No</td>
<td>23</td>
</tr>
<tr>
<td>4</td>
<td>46</td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>282</td>
<td>Yes</td>
<td>945</td>
</tr>
</tbody>
</table>

![Graph showing R² = 0.87](image.png)
Conclusions

- Our main focus has been on testing AC, however:
  - MTO has a long history using HWT for investigations and new mixes
  - The use of swelling after MIST conditioning is promising and warrants further investigation
  - Expect to start evaluating various crack predicting mix tests this year
  - Establishing a mix test for cracking, will be Ontario’s first step toward testing production mix for acceptance and will provide Contractors with a tool to use a balanced mix design
Questions?

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